22086108

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**CHEMISTRY**
**HIGHER LEVEL**
**PAPER 2**

Thursday 8 May 2008 (afternoon)

2 hours 15 minutes

Candidate session number

| 0 | 0 | | | | | | | |
|---|---|---|---|---|---|---|---|---|

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all of Section A in the spaces provided.
- Section B: answer two questions from Section B. Write your answers on answer sheets. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the numbers of the questions answered in the candidate box on your cover sheet and indicate the number of sheets used in the appropriate box on your cover sheet.



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## SECTION A

*Answer **all** the questions in the spaces provided.*

**1.** The value of ***x*** in $Fe(NH_4)_2(SO_4)_2 . xH_2O$ can be found by determining the amount, in moles, of sulfate in the compound.
A 0.982 g sample was dissolved in water and excess $BaCl_2(aq)$ was added.
The precipitate of $BaSO_4$ was separated and dried and found to weigh 1.17 g.

(a) Calculate the amount, in moles of $BaSO_4$ in the 1.17 g precipitate. *[2]*

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(b) Calculate the amount, in moles, of sulfate in the 0.982 g sample of $Fe(NH_4)_2(SO_4)_2 . xH_2O$. *[1]*

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(c) Calculate the amount, in moles, of iron in the 0.982 g sample of $Fe(NH_4)_2(SO_4)_2 . xH_2O$. *[1]*

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(d) Determine the mass of the following present in the 0.982 g sample of $Fe(NH_4)_2(SO_4)_2 . xH_2O$. *[3]*

(i) Iron

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(ii) Ammonium

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(iii) Sulfate

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*(This question continues on the following page)*

*(Question 1 continued)*

(e) Use your answer from part (d) to determine the amount, in moles, of water present in the 0.982g sample of $Fe(NH_4)_2(SO_4)_2 . xH_2O$. *[2]*

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(f) Determine the amount, in moles, of $Fe(NH_4)_2(SO_4)_2$ and hence the value of ***x***. *[2]*

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**2.** (a) The mass spectrometer is used to investigate the isotopic composition of elements. Thallium has two isotopes $^{203}_{81}Tl$ and $^{205}_{81}Tl$.

(i) State the symbols of the two singly charged ions that would form in the mass spectrometer. *[1]*

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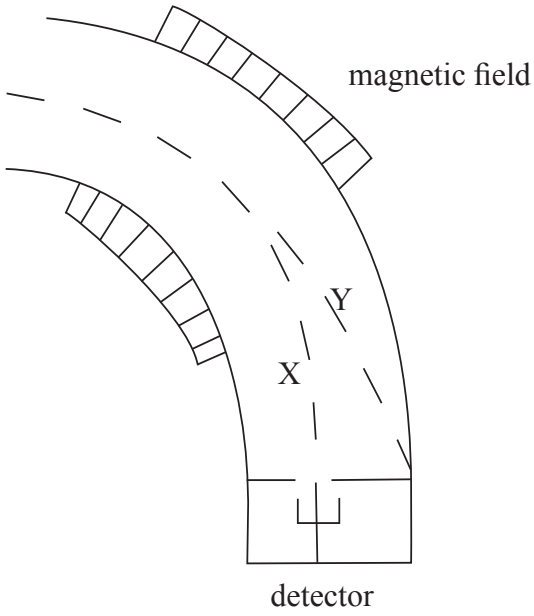
(ii) State which ion will follow the path marked **X** on the diagram. *[1]*

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(iii) Some doubly charged ions form in the mass spectrometer. Suggest with a reason whether they would be deflected less than or more than the ions at **X** and **Y**. *[2]*

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(b) Naturally occurring boron consists of the two isotopes, $^{10}B$ and $^{11}B$. The relative atomic mass of boron is 10.81. Determine the percentage abundance of these isotopes. *[2]*

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**3.** Lactic acid, $CH_3CH(OH)COOH$, is a weak monoprotic acid ($K_a = 1.40 \times 10^{-4}$ mol dm$^{-3}$).

(a) Write an equation for the reaction of lactic acid with water. *[2]*

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(b) State the ionization constant expression, $K_a$, for lactic acid. *[1]*

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(c) Calculate the $[H^+]$ of a 0.250 mol dm$^{-3}$ solution of lactic acid. *[2]*

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(d) Calculate the $[H^+]$ of a buffer solution of 1.00 dm$^3$ volume, containing 0.250 mol dm$^{-3}$ of lactic acid and 0.125 mol dm$^{-3}$ of sodium lactate. *[2]*

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(e) Explain why the two values of $[H^+]$ in (c) and (d) are different using Le Chatelier's principle. *[2]*

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**4.** (a) Explain what is meant by the term *isomers*? *[1]*

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(b) Draw **two** structural isomers for each of the following with **different functional groups**. In each case, describe a chemical test and the results obtained, which would distinguish between the two structural isomers.

(i) $C_3H_6O$ *[4]*

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(ii) $C_3H_6O_2$ *[4]*

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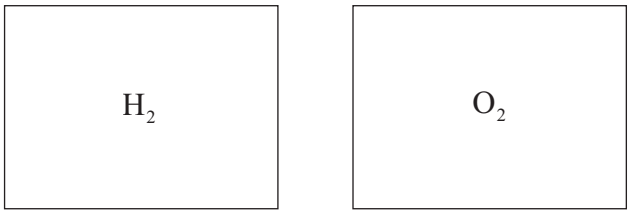
**5.** Two 1.00 $dm^3$ containers **A** and **B** each contain 2.00 g of the gas indicated at 25.0°C.




**A** **B**

(a) Calculate the pressure in container **B**. *[3]*

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(b) Deduce **without** calculation whether the pressure in **A** is higher or lower than container **B** and explain your answer. *[2]*

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## SECTION B

*Answer **two** questions. Write your answers on the answer sheets provided. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.*

**6.** (a) The decomposition of solid barium carbonate is given by the following equation:

$$BaCO_3(s) \rightleftharpoons BaO(s) + CO_2(g)$$

| Compound | $BaCO_3(s)$ | $CO_2(g)$ | $BaO(s)$ |
|---|---|---|---|
| $\Delta H_f^{\ominus}$ / kJ mol$^{-1}$ | –1219 | –394 | –558 |
| $S^{\ominus}$ / JK$^{-1}$ mol$^{-1}$ | +112 | +214 | +70 |

(i) Calculate the value of $\Delta G^{\ominus}$ in kJ mol$^{-1}$ at 25°C. *[6]*

(ii) State with a reason whether the reaction is spontaneous at 25°C. *[1]*

(iii) Determine the minimum temperature above which this reaction is spontaneous. Explain your answer. *[4]*

(b) Draw the Lewis structures of the following molecules. Use the VSEPR theory to predict the shape of each molecule.

(i) $XeF_4$ and $XeO_4$ *[4]*

(ii) $PF_5$ and $IF_5$ *[4]*

(c) Transition elements form complexes such as $[Fe(Cl)_4]^-$ and $[Fe(CN)_6]^{4-}$.

(i) Identify the feature of both $Cl^-$ and $CN^-$ that enables them to form these complexes and name the type of bond formed. *[2]*

(ii) Deduce the oxidation state of iron in each of the complex ions. *[2]*

(iii) State **two** characteristic properties of transition metals other than complex formation and variable oxidation state. *[2]*

**7.** (a) The oxidation of nitrogen monoxide takes place as follows:

$$2NO\,(g) + O_2(g) \rightarrow 2NO_2(g)$$

The following experimental data was obtained at a constant temperature.

| Experiment | Initial [NO] / mol $dm^{-3}$ | Initial [$O_2$] / mol $dm^{-3}$ | Initial rate / mol $dm^{-3}s^{-1}$ |
|---|---|---|---|
| 1 | $3.50\times10^{-2}$ | $1.75\times10^{-2}$ | $3.75\times10^{-3}$ |
| 2 | $3.50\times10^{-2}$ | $3.50\times10^{-2}$ | $7.50\times10^{-3}$ |
| 3 | $7.00\times10^{-2}$ | $7.00\times10^{-2}$ | $6.00\times10^{-2}$ |

(i) Deduce the order of reaction with respect to $O_2$ and with respect to NO. *[2]*

(ii) State the rate expression for the reaction. *[1]*

(iii) Calculate the value of the rate constant and state the units. *[2]*

(iv) Calculate the expected rate of reaction if the reactants from experiment 2 were placed in a container of twice the original volume. Explain your answer. *[2]*

(v) Suggest a possible two step mechanism that is consistent with the rate expression. Identify the rate-determining step. *[3]*

(b) The reaction in (a) is faster at 323 K than at 298 K. Explain the increase in rate in terms of collision theory and Maxwell-Boltzmann energy distribution curves. *[5]*

*(This question continues on the following page)*

*(Question 7 continued)*

(c) The following equilibrium is involved in the industrial production of nitric acid from ammonia.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H^{\ominus} = -910 \text{ kJ mol}^{-1}$$

Describe the effect, if any, of each of the following changes on the equilibrium concentration of nitrogen monoxide in a particular equilibrium mixture, give a reason in each case.

(i) Increasing the pressure, at constant temperature *[2]*

(ii) Increasing the temperature, at constant pressure *[2]*

(iii) Addition of a heterogeneous catalyst, at constant pressure and temperature *[2]*

(d) Deduce the equilibrium constant expression, $K_c$, including units for the forward reaction in part (c). *[2]*

(e) Identify which of the changes in part (c) will affect the value of $K_c$ and predict whether the value of $K_c$ will increase or decrease. *[2]*

**8.** (a) Electrolysis of an aqueous solution of copper(II) sulfate, $CuSO_4$, can be carried out using platinum electrodes.

(i) State an equation for the half-reaction occurring at the positive electrode (anode) and **one** observation that could be made as a result. *[2]*

(ii) State an equation for the half-reaction occurring at the negative electrode (cathode) and **one** observation that could be made as a result. *[2]*

(iii) Describe **two** changes or observations in the electrolyte as result of these half reactions. *[2]*

(iv) Determine the relative amount, in moles, of products formed at each electrode. *[1]*

(v) Identify another compound which will form the same products at the positive and negative electrodes. *[1]*

(vi) The same process is carried out using copper electrodes instead of the platinum electrodes. Describe the changes or observations that take place at both the electrodes and in the electrolyte. *[3]*

(b) Identify **two** factors that affect the quantity of copper produced during the electrolysis of an aqueous copper(II) sulfate solution. *[1]*

(c) Consider the following half cell reactions and their standard electrode potentials.

$$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s) \qquad E^{\ominus} = -0.23V$$
$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O\,(l) \qquad E^{\ominus} = +1.51V$$

(i) State the conditions needed for the electrode potentials to be described as standard. *[1]*

(ii) Deduce a balanced equation for the overall reaction which will occur spontaneously when the two half cells are connected. *[2]*

(iii) Identify the reducing agent in the above reaction and determine the change in oxidation number for the **oxidizing agent**. *[2]*

(iv) Determine the cell potential when the two half cells are connected. *[1]*

(v) Draw and label a diagram of the voltaic cell from part (c). Indicate the anode, cathode, the direction of the electron movement and ion flow. *[5]*

(d) Outline **two** differences between an electrolytic cell and a voltaic cell. *[2]*

**9.** (a) A hydrocarbon contains 85.6 % by mass of carbon and has a molar mass of 56.1 g $mol^{-1}$.

(i) Determine the empirical and molecular formulas of the hydrocarbon. *[3]*

(ii) Draw the structure of the unsaturated branched isomer and predict the ratio of the peak areas in its $^1H$ NMR spectrum. *[2]*

(iii) The second structural isomer of the hydrocarbon is unsaturated and symmetrical. Draw its structure and state its name. *[2]*

(iv) Draw the structure of the third structural isomer of this hydrocarbon which is unsaturated, unbranched and unsymmetrical. This isomer is formed when an alcohol is heated with concentrated sulfuric acid. Identify the type of reaction occurring and deduce the structure of an alcohol that forms this isomer. *[3]*

(b) The hydrolysis of 2-bromo-2-methylbutane by 0.10 mol $dm^{-3}$ potassium hydroxide solution to form 2-methylbutan-2-ol is an example of an $S_N1$ reaction.

(i) Explain how this $S_N1$ reaction occurs, using curly arrows to represent the movement of electron pairs, and showing the structure of the organic intermediate. *[4]*

(ii) Identify the rate determining step and state a reason for your choice. *[1]*

(c) State and explain whether the rate of each of the following reactions is greater than, less than or equal to the rate of the reaction in part (b).

(i) 2-chloro-2-methylbutane is reacted with 0.10 mol $dm^{-3}$ KOH (aq) at the same temperature. *[1]*

(ii) 2-bromo-2-methylbutane is reacted with 0.20 mol $dm^{-3}$ KOH (aq) at the same temperature. *[1]*

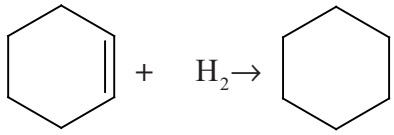
*(This question continues on the following page)*

*(Question 9 continued)*

(d) (i) Discuss the structure of benzene including the hybridization and bond angles present. *[4]*

(ii) State, with a reason, the number of main peaks in the $^1$H NMR spectrum of benzene. *[2]*

(e) (i) Cyclohexene reacts with hydrogen to form cyclohexane. *[1]*




$\Delta H^{\ominus} = -120 \text{ kJ mol}^{-1}$

Calculate the enthalpy change of hydrogenation of benzene to cyclohexane, assuming it has the cyclohexatriene  structure.

(ii) The experimental value for the hydrogenation of benzene to cyclohexane is – 207 kJ mol$^{-1}$. Explain why this value differs from the value calculated in (e) (i). *[1]*